Feedback of Coupled Thermal-Hydrological-Chemical Processes on Flow in Unsaturated Fractured Rock: Application in Seepage Modeling Studies

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Abstract

Seepage refers to dripping of water into an underground tunnel. When hot radioactive waste is placed in tunnels situated in unsaturated fractured rock, groundwater near the tunnel undergoes vaporization and boiling. Subsequently, vapor migrates out of the matrix into fractures, moving away from the tunnel through the permeable fracture network by buoyancy, by the increased vapor pressure caused by heating and boiling, and through local convection. In cooler regions, the vapor condenses on fracture walls, where it drains through the fracture network. Slow imbibition of water thereafter leads to gradual rewetting of the rock matrix.

The chemical evolution of waters, gases, and minerals is intimately coupled to the thermal-hydrological (TH) processes discussed above. Amorphous silica precipitates from boiling and evaporation, and calcite from heating and CO_2 volatilization. The precipitation of amorphous silica, and to a much lesser extent calcite, results in long-term permeability reduction. Evaporative concentration also results in the precipitation of gypsum (or anhydrite), halite, fluorite and other salts. These evaporite minerals eventually redissolve during the collapse of the boiling front, however, their precipitation results in a significant temporary decrease in permeability. Reduction of permeability is also associated with changes in fracture capillary characteristics. In short, the coupled thermal-hydrological-chemical (THC) processes dynamically alter the hydrological properties of the rock, and influence groundwater flow pattern.

A model based on the TOUGHREACT reactive transport software (Xu et al., 2006) is presented here to investigate the impact of THC processes on groundwater flow near an emplacement tunnel at Yucca Mountain, Nevada. We show how transient changes in hydrological properties caused by THC processes often lead to local flow channeling and saturation increases above the tunnel. Such local flow channeling may lead to seepage, whereas no seepage is predicted if the feedback of THC processes on flow is ignored.

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